Executive Summary of

Virtual Regional Transmission Organizations And the Standard Market Design

A Conceptual Development with Illustrative Examples

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VIRTUAL REGIONAL TRANSMISSION ORGANIZATION

Stephen T. Lee

The industry is divided and at a crossroad. Restructuring and market operation failed in California, and energy trading companies saw their stock values almost disappear. Many utility executives and many states have now turned away from the power market experiment, even as major RTOs and ISOs continue their development plans. It is certain that the industry will stay in a state of flux for a few more years before a consensus business model can emerge, if indeed one does. During this period, it is vital that reliability of power supply be maintained while the RTO formation process continues under FERC's proposed Standard Market Design (SMD).

FERC Order 2000 envisioned the formation of RTOs with large enough geographical sizes that market efficiency can be maximized by enabling free flows of competitive wholesale electricity inside each RTO. Due to resistance of various types, voluntary formation of RTOs fell short of FERC's original goal of having only four or five RTOs operating the transmission grids of power markets in the U.S. This means that there will be seams between RTOs in the Eastern Interconnection and the Western Interconnection. A single seamless power market within each Interconnection is still elusive. Eliminating the seams requires coordinated congestion management and market operation.

Reliability of an interconnection may not be taken for granted. A competitive power market's profit incentive tends to push wholesale power transfers to the limits of the transmission grid. NERC criteria establish a buffer zone of one contingency away from violation of operating limits. If simultaneous multiple contingencies were to happen during heavy congestion, wide-spread blackouts may occur. Increasing levels of congestion have been seen in the Eastern Interconnection for the last few years. With little transmission investment due to the lack of financial incentives to build, the prospect for congestion and reliability is not good. An analysis in this paper used the historical hourly transfer patterns collected by the EPRI TagNet program from the NERC electronic tags (E-tags) submitted for all point-to-point wholesale power transactions in the Eastern Interconnection. Based on results of the Eastern Interconnection Summer 2002 pre-season reliability study, a projection of congestion under future load growth came up with the following observation:

- *If there is no new transmission capacity built in the Eastern Interconnection in the next five years, during **half of the summer period**, operators will face congestion which may result in curtailments of the wholesale power market.*

While the industry awaits FERC to provide the financial incentives for transmission investments, coping with congestion is crucial for reliability. Up to now, the NERC Interchange Distribution Calculator (IDC) has served as a central data system to address the seams of congestion in the Eastern Interconnection. It is an equitable and transparent Transmission Loading Relief (TLR) process for curtailing wholesale point-to-point transactions and firm network loads to relieve flowgate congestion caused by parallel flows. With Locational Marginal Pricing (LMP), congestion inside the RTO is managed by solving a security-constrained economic dispatch, i.e., re-dispatching the generation so that no transmission lines are overloaded. If multiple RTOs exist in the same interconnection, overloads on certain transmission lines external to an RTO may be partially caused by that RTO. Relieving congestion on these jointly-impacted flowgates therefore requires coordinated and equitable re-dispatches or TLRs by these RTOs and other operating entities. As more RTOs and ISOs implement LMP and no longer submit E-tags to the IDC, reliability may be adversely affected if the hardware and software that glue the seams together do not evolve with the new business and organizational framework.

Virtual RTO Architecture

In this paper, EPRI describes the technical concept of a virtual Regional Transmission Organization (vRTO) in the context of the SMD. The purpose is to provide potential technological solutions to the power industry for maintaining a reliable and efficient wholesale power market during its restructuring and transition.

A virtual RTO is not a single legal entity. It is an idea for making business processes, computers and data communications of an interconnection's operating entities work together to achieve the benefits of a single RTO. In other words, the virtual RTO concept is an attempt to achieve a seamless power market within an interconnection which consists of multiple RTOs or ISOs and other grid operators. While most of the RTOs and ISOs adopt or plan to adopt the LMP market model envisioned in the SMD, other grid operators may not. They may continue to use and support bilateral point-to-point transactions and provide network services. In this mixed operation, three questions are currently among the most critical ones. They are:

1. How would the operating entities maintain reliability in the interconnection?
2. How would they achieve a competitive and globally efficient power market?
3. If that global market efficiency is achieved, how would they ensure a win-win outcome for all customers in every region?

The objective of this paper is to explore the idea for two or more operating entities in an interconnection which use LMP or security-constrained economic dispatch to iterate between their computer systems in such a way as to assure no transmission bottleneck anywhere within the interconnection is congested beyond its operating limit. By solving the congestion management problem across the seams, reliability for the interconnection will be maintained. Furthermore, this paper shows that there is another iterative process which will likely enable the LMP prices in the constituent systems to converge to the optimal single-market prices. Thus, the first two questions seem to be answered.

A solution to the third question was suggested in this paper. It is the method of financial settlements between RTOs which uses reconstructed dispatches to determine the total net benefit of the global market and then allocates the net benefit to all customers so that all customers come out a winner.

The technical foundation for such convergence was explored and described through illustrative examples. It was shown that a common power system model with real-time data exchange on critical data forms part of that foundation. The degree of data aggregation and modeling approximation was discussed, recognizing the practical issues of data availability, commercial sensitivity and degree of accuracy required. Some of these real-time data exchange will improve the accuracy of the current NERC TLR method implemented on the NERC IDC. Balanced sets of Portfolios representing an LMP dispatch solution in an RTO could replace previous point-to-point NERC E-tags in that RTO as the means to share data on transactions that affect other systems' power flows. Casting the detailed generator by generator solution into aggregated outputs of Cohesive Electrical Zones (CEZs) respects commercial sensitivities. By standardizing on an interconnection-wide set of CEZs, both point-to-point and Portfolio E-tags can co-exist within the IDC and in fact will increase the accuracy of the IDC. The architecture of this virtual RTO system is shown in Figure 1.

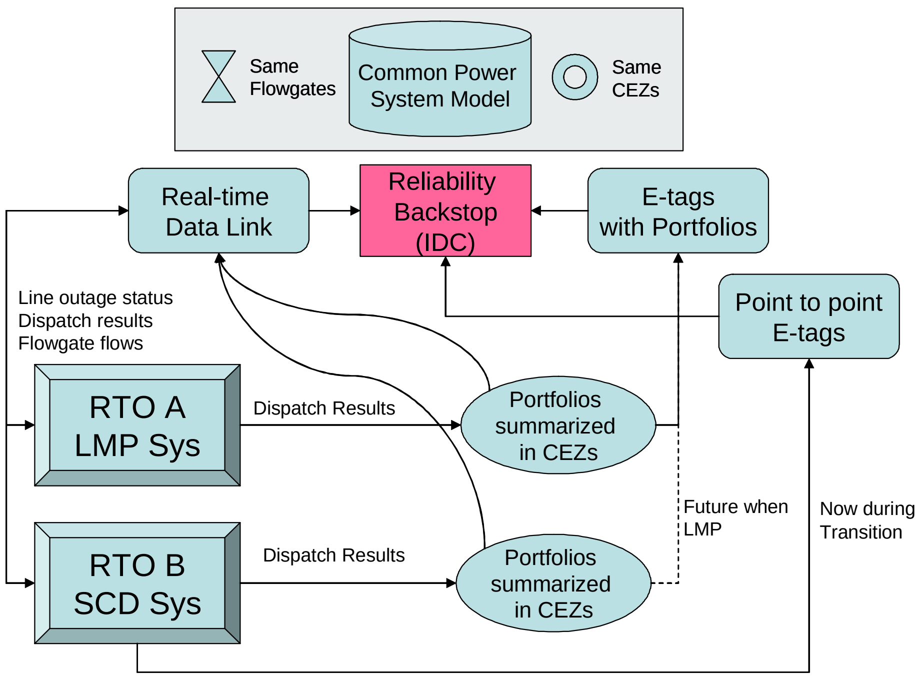

Figure 1 Virtual RTO Architecture with Glue

As shown in the top part of the diagram, a Common Power System Model of the entire interconnection is consistently applied to all modeling, along with standard flowgates and Cohesive Electrical Zones (CEZ) defined for the entire interconnection. The CEZs are basically groups of generators (or loads) that are closely coupled to one another electrically, and they have similar impacts on external flowgates. The diagram is illustrated for two RTOs but it can be extended to include more RTOs. An RTO may use LMP or a Security Constrained Economic Dispatch (SCD) for its congestion management. As each RTO solves its coordinated dispatch problem (LMP or SCD), the dispatch results are summarized in terms of net power productions (or demands) of the CEZs, and then sent in two data paths as balanced portfolios. There could be a firm set and a non-firm set of balanced portfolios. For an RTO that implements LMP, the balanced portfolios will be sent as a new type of E-tags to the IDC and also sent as real-time data through the NERC Inter-regional Security Network (ISN). Other real-time data will also be exchanged through the real-time network. The fact that point-to-point E-tags can co-exist with Portfolio E-tags in the IDC is shown in the diagram. As an RTO moves from the current TLR-based transaction management to an LMP-based system, it can switch from point-to-point E-tags to the Portfolio E-tags, and the transition can be managed without degrading the accuracy of the IDC. In fact, moving the industry to the implementation of CEZs for point-to-point E-tags will also improve the accuracy of the IDC in the mean time, due to enhanced granularity in the IDC model resulting from using CEZs instead of control areas as the sources and sinks of the transactions.

Coordinated Congestion Management Procedure

The first iterative procedure for the virtual RTO is designed to solve the coordinated congestion management problem. It is summarized in the following steps.

1. Each RTO has the base case power system model of the entire interconnection set up specifically for its own use.
2. Each RTO sends the network status of its grid to a central computer and receives the network status of other RTOs. It then updates the power system model of the interconnection in its control center to reflect changes in the network status in the interconnection. Each RTO also sends and receives other real-time data.
3. Each RTO solves its SCD problem (or an equivalent congestion management problem) that explicitly models the jointly-impacted flowgate constraints, with the assumptions that the dispatch decisions of the other RTOs remain constant. This step is done at the regular computation frequency at each RTO.
4. Each RTO sends its dispatch solution immediately to the other RTOs. As soon as it receives the dispatch solution from another RTO, it goes back to Step 3 and keeps solving its SCD problem until there are no changes in its solution from the previous solution. When the SCD problems for all RTOs no longer change, the converged solution is found.

Convergence to a globally feasible solution is illustrated in the paper by two examples. In both cases, convergence is achieved. However, the second example shows some difficulty.

A Reliability Backstop System Is Still Needed

The coordinated congestion management procedure described above may not produce a feasible solution under all circumstances. It is conceivable that under heavy congestion in the interconnection due to a combination of high load levels and high inter-RTO power transfers, a globally feasible solution would involve dropping firm loads in one or more RTOs in the interconnection. In such events, there are issues of equity among the RTOs as to the proper shares of the load curtailment.

It may be that with sufficient iterations between the RTOs using the Coordinated Congestion Management Procedure above, some of these problems may be solved. However, reliability may be severely impacted in the mean time. It may also be possible that the coordinated procedure above may not work well during the time period of a day when load is increasing or decreasing rapidly. Thus, to handle these potentially unanticipated situations, it is vital that a reliability backstop system be available to maintain reliability in the interconnection.

The Interchange Distribution Calculator (IDC) is the reliability backstop system at the present time in the Eastern Interconnection. The question is how the IDC will evolve in the near future to remain relevant and vital as the reliability backstop in the new world where LMP is implemented in part or all of the interconnection.

Convergence to Global Market Prices

Two methods of global LMP market price convergence are conceivable for a virtual RTO.

- The first is through the human market loop. In this scheme, the generators in the entire interconnection should be free to enter into any or all of the constituent markets in whole or in parts during a short enough time interval, e.g., one hour or less, so that marketeers can arrange for competitive power sales across RTO boundaries. They will facilitate price convergence by seeking out, in both real time and in day-ahead markets, opportunities to profit by making inter-RTO transactions.
- The second method is to permit each RTO to bid into the day-ahead and the real-time markets of the other RTOs with its available economy energy after balancing its internal market. The bids will be in the form of one or more cost curves (based on the prices bid into its internal market) with maximum MW limits from sources located at certain CEZs or marginal generating units. An iterative process requiring real-time exchange of the bid curves can be set up whereby each RTO solves its LMP with the external bid curves and then revising its own bid curves to the other RTOs for their next iteration. An example in this paper shows that the iterative process converges to a condition close to the single LMP global solution although it cannot be proven mathematically that convergence is guaranteed. More research should be done in this area.

Financial Settlement for Equitable Sharing of Market Savings

Along with convergence to the global market prices comes the problem of equitable sharing of market benefits. Regions with inexpensive power plants will likely see some portion of that cheap energy going to other regions where local generation is more expensive. The effect of market efficiency, without equitable sharing of that saving, is to increase the cost of electricity in the exporting regions and to lower the cost of electricity in the importing regions. Why would consumers and state regulators want market efficiency if it means that the cost of electricity to them and to their constituents will go up?

In the vertically integrated utility world, such economy interchanges took place regularly and the equity issue was resolved by setting the transaction price at the middle between the incremental costs of the seller and the buyer, so that both sides came out ahead and shared the savings equally. With a win-win solution, economy interchanges made practical sense to every party.

With global market convergence, is there a system whereby everyone comes out ahead?

One answer is to implement a shared savings formula among the RTOs in an interconnection, such that the savings all flow to the customers in each RTO. The generators will still make their profits because their bid prices already include profits. The exact formula can be negotiated among the stakeholders in the entire interconnection. One simple approach is used in this paper for illustration purpose only. That approach is as follows:

1. Perform a reconstruction of each RTO’s dispatch for a given hour with limitations put on the generators in that RTO so that they cannot participate in the other RTO power markets, except for firm contracts. In other words, out-of-market non-firm sales are assumed to be unavailable. Then the optimal dispatch for the RTO will reflect the

benefits of the local generation meeting the local demand. Add the costs of all the RTOs thus reconstructed.

2. Add the actual costs of all the RTOs, as operated for that hour, to give the total interconnection's cost.
3. Subtract the total actual cost in step 2 from the total cost in step 1 to compute the realized cost savings due to interconnected market operation.
4. Take the cost savings in step 3 and prorate it among the RTOs in proportion to their reconstructed costs computed in step 1.
5. Each RTO takes its reconstructed operating cost for the hour in step 1 and subtract from it the prorated cost savings in step 4. The result is the final settled cost for the RTO.
6. The RTOs exchange funds, through accounting, so that each RTO will realize the settled costs at the end of an accounting period.

A conceptual example of this is illustrated in Figure 2.

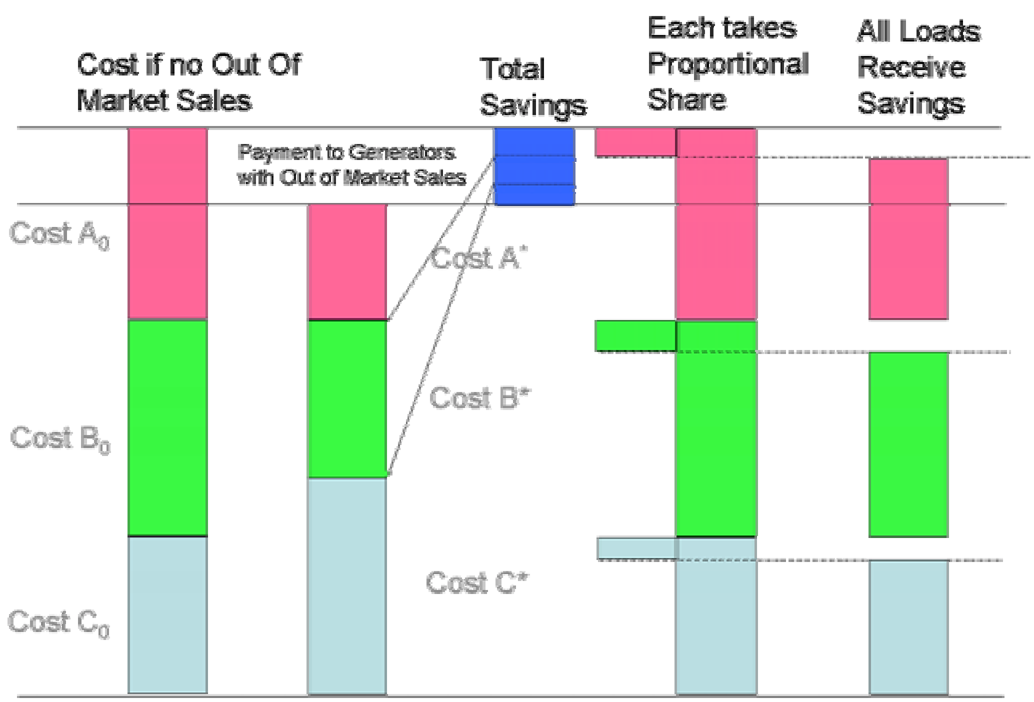

Figure 2 Sharing of Market Efficiency Savings among RTOs in an Interconnected Power Market assuming three RTOs, A, B and C.

The concept of equitable sharing of energy cost savings due to market efficiency among the customers of the constituent RTOs of an interconnected wholesale power market was illustrated by an example in this paper. This may provide a win-win system whereby market efficiency due to free-flowing and economic out-of-market sales can be achieved while the savings due to these economy sales are distributed equitably to all customers, so that all customers in all regions come out winners.

Conclusion

In conclusion, this paper has proposed several concepts for solving some of the difficult and unsolved problems arising from the evolution of the power industry through a series of power market restructuring. As a research organization of the power industry, EPRI takes no position on the regulatory policies affecting the industry. To be most useful to the power industry, EPRI develops technologies in anticipation of the needs of its members. With the industry at a fork of the road choosing between market reforms and more regulation, the industry cannot afford to stand still. The wise course of action seems to be that of moving ahead with infrastructure enhancements that will benefit the industry regardless of which road it takes, including going down both paths.

The virtual RTO is such a course of action. The industry needs a technical solution that can accommodate a business model with both a market system (currently in existence or in the developmental stages) and those systems with more regulation. These systems need to function well together, in a seamless interconnection, with high reliability and economic efficiency. The inter-regional IT infrastructure, including data communication and computational tools outlined in this paper, represents advancements into the future. They pave the way for greater coordination among the operating entities. They can meet the needs of both types of grid operators. With such an infrastructure in place, the industry can change its mind and still the power grid will continue to serve customers reliably and efficiently.

It is important for the industry to resist shortcut patches to the inter-regional IT infrastructure, in the rush to meet deadlines of restructuring. Such rushes to operation, for example, in the California power market reform in 1998, expose the infrastructure to unintended consequences. Also, once in place, such IT systems are hard to remove. Poorly designed systems will then place constraints on future deployment of alternative systems and make them less optimal. Worse still, if there are faulty logics in the IT systems or single points of hardware or software failures, the reliability of the entire interconnection may be affected seriously. Therefore, one lesson learned from failed market experiments is also relevant to power system reliability -- Test the proposed system thoroughly before putting it into operation. A billion-dollar airplane is subject to numerous wind tunnel tests before it flies. Should not a trillion-dollar power market thoroughly test its reliability cornerstone before putting a new IT system into operation?

Another problem is a political one -- that of local resistance to redistribution of economic benefits or paying for others' benefits. Public benefits require a sharing of costs. If one only looks at direct benefits to oneself from a "public" project, one may not want to pay for it. On the other hand, if a "public" project is built, everyone would not mind benefiting from it. The concept of using financial settlements to perform redistribution of costs and benefits is an important technical solution to that political problem. It will ensure that all customers come out a winner, sharing equitably the total net benefits of having a single and most efficient power market. Computers can be used to make those calculations objectively. The allocation formula can be decided and negotiated by the interested parties to reach a consensus. It should be possible to persuade all stakeholders to adopt a win-win solution with a non-zero gain. Market efficiency indeed would provide a non-zero gain in which everyone can share.